

Guide to Documenting Cost and Performance for Remediation Projects

Prepared by Member Agencies of the
Federal Remediation Technologies Roundtable

U.S. Environmental Protection Agency
Department of Defense
U.S. Air Force
U.S. Army
U.S. Navy
Department of Energy
Department of Interior

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NOTICE

This document has been subjected to administrative review by all Agencies participating in the Federal Remediation Technologies Roundtable, and has been approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

The purpose of this Guide is to foster the use of consistent procedures to document cost and performance information for projects involving treatment of contaminated media. In short, it provides site remediation project managers with a standardized set of parameters to document completed remediation projects. Standard reporting of data will broaden the utility of the information, increase confidence in the future effectiveness of remedial technologies, and enhance the organization, storage, and retrieval of relevant information. Through greater coordination, Federal Agencies hope to improve data collection and dissemination, and thus to increase the effectiveness of hazardous waste cleanups.

This Guide was developed by the Federal Remediation Technologies Roundtable (the Roundtable). The Roundtable was created to exchange information on hazardous waste site remediation technologies, to consider cooperative efforts of mutual interest, and to develop strategies leading to a greater application of innovative technologies. Roundtable member Agencies, including the U.S. Environmental Protection Agency (EPA), the U.S. Department of Defense (DoD), the U.S. Department of Energy (DOE), and the U.S. Department of the Interior (DOI), expect to complete many site remediation projects in the near future. These Agencies recognize the importance of documenting the results from these cleanups, and the benefits to be realized from greater coordination of such efforts between Agencies.

The Roundtable established an Ad Hoc Cost and Performance Work Group, formed with representatives from government Agencies, professional associations, and public interest groups, to improve the documentation of future remediation projects. A goal of the Work Group was to determine what information would be practical and useful to specify for inclusion in all reports. This Guide is the result of several Work Group meetings held in 1993 and 1994. The primary contributors to this effort are listed at the end of this report.

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Roundtable

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1.0 INTRODUCTION

This Guide provides the recommended procedures for documenting results from completed full-scale hazardous waste site remediation projects. The Guide was developed by the Federal Remediation Technologies Roundtable (the Roundtable) to more effectively coordinate the activities of its member Agencies and to assist in capturing their experience from these projects. Roundtable member Agencies include the U.S. Environmental Protection Agency (EPA), the U.S. Department of Defense (DoD), the U.S. Department of Energy (DOE), and the U.S. Department of the Interior (DOI).

1.1 Background

Federal Agencies are involved in a variety of activities to improve the efficiency of their remediation efforts. These activities include the evaluation of new and improved treatment technologies through field demonstration projects. For example, Federal and State Agencies are participating in seven different demonstration programs to test new processes with the hope of expediting their acceptance in the marketplace. These demonstration projects are designed as technical evaluations of treatment technologies and involve extensive data collection and documentation.

In addition, Federal and State Agencies are now participating in the remediation of hazardous waste sites using both conventional and innovative technologies. These full-scale cleanups also present an important opportunity to gather data. The projects may entail documenting the achievement of prescribed cleanup goals or other contract objectives. Currently, the contents of project documentation vary widely and much of the first-hand experience of project personnel is not routinely documented.

The Roundtable Agencies recognize the value of the data and experience gained from these full-scale cleanups and agree that gathering cost and performance information for remedial technologies should be a priority. At a Roundtable meeting in May 1993, an Ad Hoc Work Group was established to assess the potential for coordinating efforts of the separate Agencies in this area. This Work Group has met four times to review relevant ongoing Federal efforts, to identify information needs, and to develop a strategy for coordinating the documentation of cost and performance information. During these meetings, which were open to the public, the Work Group participants discussed issues concerning documentation of cost and performance data and reviewed preliminary draft reporting formats. In addition, the Work Group reviewed draft agency reports to identify areas for potential standardization.

DoD, DOE, and EPA have efforts underway to document full-scale remediation projects. Their reports provide a primary source of cost and

performance data and include information on matrix characteristics, treatment system design and operation, and observations and lessons learned in cost and performance. EPA prepared summary reports using a standardized reporting format for 17 remediation projects completed at Superfund sites. EPA's reports document cost and performance for innovative technologies such as bioremediation, soil vapor extraction, thermal desorption, and soil washing. DoD and DOE prepared cost and performance summaries for 21 remediation projects. Although DoD's and DOE's reports have a consistent set of topics, the content of each topic is structured on a site-specific basis. The emphasis of these reports is to produce a document with signed certifications from the Remedial Project Manager(s) representing EPA, State Agencies, and other pertinent organizations, and also to provide information to facilitate future permitting and the development of presumptive remedies.

The Work Group concluded that a coordinated and consistent approach to the collection of data across all Agencies would broaden the utility of the information, increase confidence in the future effectiveness of remedial technologies, and enhance the organization, storage, and retrieval of relevant information. The Work Group also concluded that each Agency should be free to determine the overall format for their reports on completed projects, as is currently being done. As a result, the Work Group identified specific subject areas with the greatest potential for use in a standardized report format, and that are most relevant to technology analysts. Specific benefits of the interagency effort to coordinate information collection and documentation include:

- Establishing a baseline for future data gathering and report preparation;
- Assisting in remedy selection by allowing a project manager to consider previous technology applications on sites with similar characteristics;
- Allowing a more meaningful comparison of technology performance, including assessments of potential presumptive remedies, by providing consistent soil characteristics and operating conditions;
- Supporting improved cost comparisons and projections through the use of a standard work breakdown structure; and
- Ensuring a minimum level of reporting quality by specifying documentation objectives for test and measurement procedures.

1.2 Overview of the Guide

This Guide presents recommended procedures for documenting cost and performance information by Roundtable Agencies. In addition to standard terminology, the basic information types include waste characteristics and operating parameters that affect the cost or performance of different technologies, measurement procedures, standardized cost breakdown, and treatment technology performance. These topics are discussed in Section 2.0. Following the discussion of each topic, an example is provided as a practical illustration of report format.

The recommended documentation procedures are relatively simple and straight-forward. The parameters were chosen because they are practical and useful, and the requested information will be relevant to future projects during the remedy selection process. The procedures were developed especially for full-scale projects to help realize the benefits associated with consistent and uniform data collection and documentation.

This Guide addresses both conventional and innovative treatment technologies, but does not include capping or other containment processes. Conventional technologies are included in this Guide because there is still much to learn from the application of these processes at hazardous waste sites. In addition, information on conventional technologies serves as a useful baseline against which the data from innovative technologies can be compared.

While developing this Guide, the notion of "minimum data sets" caused some confusion. To clarify, it is preferable to consider the recommended procedures as constituting desirable data sets. The information should not be viewed as minimum requirements for adequate documentation or, for that matter, for responsible remedy selection. Further, collection of only the data recommended in Section 2.0 may not be adequate to satisfy all project-specific data requirements. For example, most project reports will include narrative site descriptions, lessons learned, and timelines; however, the format for these presentations is left to the individual Agencies.

Section 3.0 of this Guide provides implementation considerations and a description of future work group activities.

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2.0 RECOMMENDED PROCEDURES

This section contains recommended procedures for documenting the following cost and performance information for completed site remediation projects:

- Standard terminology;
- Waste characteristics and operating parameters affecting treatment cost or performance;
- Measurement procedures;
- Standardized cost breakdown; and
- Performance.

Tables noted in the text may be found at the end of this Guide.

2.1 Standard Terminology

The use of standard terminology to describe site background, site characteristics, and treatment systems will facilitate the storage and retrieval of information, including the future use of electronic search routines. The parameters were chosen to highlight important features of the remediation projects, so that they can be used in the future as keywords for site screening. For each parameter, the Guide proposes corresponding terms as possible descriptors.

2.1.1 Site Background

Site background information is necessary to describe the historical activity that generated the contamination and the waste management practices that contributed to the contamination. Historical activities that generated contamination may be described using the 4-digit Standard Industrial Classification (SIC) Code that best represents the historical activity responsible for the contamination at a site. Appendix A shows examples of SIC codes most likely to apply to contaminated sites. These examples were derived from the SIC Codes identified by the Superfund program to be most closely associated with contaminated sites. For the purpose of this Guide, some additional codes have been created to address activities not described by current SIC codes. Four-digit SIC codes are described in the *Standard Industrial Classification Manual*, published by the Office of Management and Budget, and available for sale from the National Technical Information Service, order no. PB87-100012. Common terminology for waste management practices that contribute to contamination are

shown in Table 1, which was derived from the Vendor Information System for Innovative Treatment Technologies (VISITT) and DoD's Installation Restoration Program (IRP).

2.1.2 Site Characteristics

Site characteristic information is necessary to describe the type of media (matrix) processed by the treatment system, the types of contaminants treated, and the characteristics of the matrix (described in Section 2.2).

Terms that describe the type of media treated are presented in Table 2. These terms were derived from information in EPA's VISITT database and the interagency Work Breakdown Structure (WBS).

Contaminant groups that were treated may be described using the terminology presented in Table 3. The terminology was derived from information in EPA's VISITT database, EPA's Superfund Land Disposal Restrictions (LDR) 6A/6B Guides, and the WBS. Specific contaminants treated within each contaminant group should also be identified (as well as the concentrations of those contaminants in the untreated matrix). The groups shown in Table 3 were selected because they are widely recognized terms. However, the groupings are not an exhaustive list for all contaminants.

2.1.3 Treatment System

Treatment technology information is necessary to identify the primary and supplemental systems (i.e., pretreatment, post-treatment, and process augmentation) used in a site remediation project. Tables 4 and 5 list common terminology for treatment technologies, which were derived from EPA's VISITT database and from the Remediation Technologies Screening Matrix and Reference Guide, July 1993, prepared jointly by EPA and the Air Force.

2.1.4 Example

An example application of the recommended procedures for standard terminology to a specific project (cleanup of the T H Agriculture & Nutrition (THAN) Company Superfund Site in Albany, Georgia) is presented below in Exhibit 1:

Exhibit 1: Example for Reporting Standard Terminology

Site Background:

Historical Activity that Generated Contamination

SIC Code: 2879 (Pesticides and Agricultural Chemicals, Not Elsewhere Classified)

Management Practices that Contributed to Contamination

Storage - Drums/Containers (storage, formulation, and distribution of pesticides)

Site Characteristics:

Media Treated

Soil (ex situ)

Contaminants Treated

Halogenated Organic Pesticides/Herbicides (including the following constituents:

4,4'-DDT, toxaphene, BHC-alpha, and BHC-beta)

Treatment System:

Primary Treatment Technology

Thermal Desorption

Supplemental Treatment Technology

Pretreatment (Solids) - Screening

Post-Treatment (Air) - Baghouse, Quench, Air Cooler, Induced Draft Fan, Carbon

Adsorption, Condenser

Post-Treatment (Solids) - Quench

Post-Treatment (Water) - Carbon Adsorption

2.2

Parameters Affecting Cost or Performance

Technology cost or performance is affected by waste characteristics and treatment technology operating conditions. Tables 6 and 7 list, on a technology-specific basis, the waste characteristics and operating conditions that should be documented for several of the most common site remediation technologies. These parameters define desirable information which may help to guide formulation of future field sampling programs during site remediation. These parameters were selected because they affect a technology's cost and performance and also because they are commonly measured in practice. The parameters represent standard data sets which will allow a consistent comparison of various applications of a particular technology.

Other items besides matrix characteristics and operating conditions are important to document because of their potential impact on cost or performance, as shown on Table 6. These include the type and concentration of contaminants, quantity of material treated, cleanup goals or requirements, and environmental setting. For example, for in situ technologies, geologic and hydrogeologic characterizations should be included in project documentation.

The parameters listed in Tables 6 and 7 represent the key factors which would be of most value to project managers who are trying to apply results from a completed cleanup to their own particular site. The collection of additional parameters will be decided on a site-specific basis and should be included in the project documentation. Tables 8 and 9 provide additional information on the methods used to measure each parameter shown in Tables 6 and 7, and on each parameter's potential effect on cost or performance (i.e., the reasons why the parameters affecting cost or performance are important).

In addition, because costs are typically reported in terms of dollars per cubic yard or per ton of soil treated, the Work Group recommends that the bulk density of soil be included in documentation for ex situ soil remediation projects (e.g., as shown on Table 6 for thermal desorption). This information will allow for comparisons of project costs in terms of costs per cubic yard and per ton of soil treated.

2.3 Measurement Procedures

Documentation of measurement procedures for many of the matrix characteristics and operating parameters is important to allow a more meaningful comparison of results among projects. It is especially important to document measurement procedures when there are different methods available or when less standardized procedures are used for measuring an individual parameter (e.g., for clay content). The use of different methods or less standardized procedures may lead to variability in results and, therefore, should be considered in cross-project comparisons. Tables 8 and 9 identify which measurement procedures are recommended for documentation.

2.3.1 Example

An application of the recommended procedures for reporting parameters affecting cost or performance to a specific project (cleanup of the Rocky Mountain Arsenal, Operable Unit 18, in Commerce City, Colorado using soil vapor extraction) is presented in Exhibits 2 and 3. In Exhibits 2 and 3, measurement procedures are shown for some parameters but not others. As shown on Tables 8 and 9 of the Guide, measurement procedures should be documented for those parameters whose results may vary due to method variability (e.g., for permeability).

Exhibit 2: Example for Reporting Matrix Characteristics Affecting Treatment Cost or Performance and Associated Measurement Procedures

Parameter	Value	Measurement Procedure
Soil Types (Soil classification and clay content)	0-35 ft. below ground surface (BGS): poorly graded sand (SP), poorly graded sand with gravel (SP), and poorly graded sand with silt (SP-SM). 35.5 ft. BGS: lean clay with sand (CL). 55 ft. BGS: poorly graded sand (SP)	Particle Size Analysis: ASTM Method D422-63
Moisture Content	4.7 to 30.9%	Gravimetric Analysis: ASTM Method D2216-90
Air Permeability	0 to ~38 ft. BGS: 167 darcys ~55 ft. BGS: 2,860 darcys	Vacuum readings were taken at five-minute intervals from P-7B and VES-4 during the system start-up until steady state conditions were observed. Vacuum readings at each location were plotted against the natural log of time. The slope and y-intercept of each plot were used in a Johnson et al., 1990, equation to predict soil permeability to air flow.
Porosity	Not Measured	---
Total Organic Carbon	Not Measured	---
Non-Aqueous Phase Liquids (NAPLs)	No evidence of NAPLs within operable unit.	Not Reported

Exhibit 3: Example for Reporting Operating Parameters Affecting Treatment Cost or Performance

Parameter	Value	Measurement Procedure
Air Flow Rate	145 to 335 cfm (total for two extraction wells)	N/A*
Operating Vacuum	0 to 30 inches of water	N/A*

*N/A - Not applicable. See Table 9. Standard measurement procedures for air flow rate and operating vacuum are available.

2.4 Standardized Cost Breakdown

An interagency group has developed a standardized work breakdown structure (WBS), which includes five levels of detail for the types of cost elements. Project cost documentation should follow the interagency WBS to the extent possible; documentation of treatment costs to the fifth level of detail is desirable and should be provided whenever possible. In addition, the documentation should identify unit costs and number of units for each cost element, as appropriate. The use of the WBS format will facilitate comparison of costs across projects, and the detailed breakout will help support extrapolation of costs to future applications. The second level WBS cost elements, which relate to the treatment processes, are shown in Exhibit 4, and further described in Table 10. The cost elements are grouped by when the activity occurs--before, during, or after treatment.

Exhibit 4: Second Level Work Breakdown Structure Cost Elements

Interagency WBS #	Cost Element
Before Treatment Cost Elements	
33 01	Mobilization and Preparatory Work
33 02	Monitoring, Sampling, Testing, and Analysis
33 03	Site Work
33 05	Surface Water Collection and Control
33 06	Groundwater Collection and Control
33 07	Air Pollution/Gas Collection and Control
33 08	Solids Collection and Containment
33 09	Liquids/Sediments/Sludges Collection and Containment
33 10	Drums/Tanks/Structures/Miscellaneous Demolition and Removal
Treatment Cost Elements	
33 11	Biological Treatment
33 12	Chemical Treatment
33 13	Physical Treatment
33 14	Thermal Treatment
33 15	Stabilization/Fixation/Encapsulation
After Treatment Cost Elements	
33 17	Decontamination and Decommissioning (D&D)
33 18	Disposal (other than Commercial)
33 19	Disposal (Commercial)
33 20	Site Restoration
33 21	Demobilization
33 9X	Other (use numbers 90-99)

The third level of the WBS identifies 68 specific types of treatment processes. The fourth level of the WBS is used to distinguish between portable and permanent treatment units. For portable treatment units, the fifth level of the

WBS identifies 12 specific cost elements directly associated with treatment, as shown in Exhibit 5.

Exhibit 5: Fifth Level Work Breakdown Structure Cost Elements

Interagency WBS # 33 XX XX 01-	Portable Unit Treatment Cost Element
01	Solids Preparation and Handling - Includes loading/unloading, screening, grinding, pulverizing, mixing, moisture control, and placement/disposal.
02	Liquid Preparation and Handling - Includes collection/storage (equalization), separation, treatment, and release/disposal (POTW, surface discharge).
03	Vapor/Gas Preparation and Handling - Includes collection/storage, separation, treatment, and release/disposal.
04	Pads/Foundations/Spill Control - May include materials and construction of facilities.
05	Mobilization/Setup - May include activities needed to prepare for startup.
06	Startup/Testing/Permits - May include activities needed to begin operation.
07	Training - May include training needed to operate equipment.
08	Operation (Short Term - Up to 3 Years) - Includes bulk chemicals/raw materials, fuel and utility usage, and maintenance and repair.
09	Operation (Long Term - Over 3 Years) - Includes bulk chemicals/raw materials, fuel and utility usage, and maintenance and repair.
10	Cost of Ownership - May include amortization, leasing, profit, and other fees not addressed elsewhere.
11	Dismantling - May include activities needed prior to demobilization.
12	Demobilization - May include removal of unit.

For permanent treatment units, the fifth level of the WBS identifies 10 specific cost elements, 8 of which are identical to the cost elements described above for portable units. For permanent units, item 05 (Mobilization/Setup) is replaced by Construction of Plant, which includes architectural, structural, mechanical, electrical, equipment fabrication/purchase, and equipment erection/installation. Items 10 through 12 are replaced with a new item 10, Mothballing, which may include costs for deactivating the treatment unit.

For Before Treatment and After Treatment Cost Elements, documentation to the second level of detail is adequate, while actual Treatment Cost Elements should be provided to the fifth level if possible.

The WBS format will be used in the future as part of federal procurements for site remediation services. Data collected through use of the WBS will be stored electronically in a Historical Cost Analysis System (HCAS). The documentation of projects using the WBS and the storage of this data in HCAS provides a mechanism for comparison of costs among documented remediation projects and also between other projects in the HCAS system. Additional information on the WBS and HCAS is presented at the end of this Guide.

2.4.1 Example

An application of the recommended procedures for a land treatment application at the Brown Wood Preserving Superfund site is presented in Exhibit 6. This example shows before and after treatment costs at the second level of the WBS, and costs directly associated with treatment at the fifth level of the WBS. It also shows unit costs for appropriate cost elements.

Exhibit 6: Example for Reporting Site Remediation Project Costs

	Cost Element	Unit Cost (\$)	No. of Units	Cost (\$)
Before Treatment Costs	Mobilization and Preparatory Work - mobilization of equipment, material, and personnel	9,827	lump sum	9,827
	Site Work - site preparation	4,781.16/ac re	5 acres	23,906
	- fence	22,610	lump sum	22,610
	Solids Collection and Containment - stockpile soil	0.53/cu. yd	3,200 cu. yds	1,696
Treatment Cost Elements	Solids Preparation and Handling - spread contaminated soil	2.77/cu. yd	3,200 cu. yds	8,864
	Mobilization/Setup - installation of clay liner	3.23/cu. yd	7,000 cu. yds	22,610
	- installation of subsurface drainage network	68,062	lump sum	68,062
	- construction of perimeter containment berms	3.29/ft	2,000 ft	6,580
	- shape retention pond	3,293	lump sum	3,293

Exhibit 6 (Continued)

	Cost Element	Unit Cost (\$)	No. of Units	Cost (\$)
	- installation of runoff drainage swales	1.15/ft	3,000 ft	3,450
	- installation of irrigation system	20,312	lump sum	20,312
	Operation (short-term - up to 3 years) - 1988 O&M (construction mgmt.)	36,883	lump sum	36,883
	- 1989 O&M (includes approximately \$40,000 for groundwater monitoring)	194,118	lump sum	194,118
	- 1990 O&M (includes approximately \$40,000 for groundwater monitoring)	80,560	lump sum	80,560
Treatment Cost Elements (Continued)	Operation (long-term - over 3 years) - 1991 O&M (groundwater monitoring and site restoration)	60,477	lump sum	60,477
	- 1992 O&M (groundwater monitoring and site restoration)	37,307	lump sum	37,307
	- 1993 O&M (groundwater monitoring and site restoration)	22,891	lump sum	22,891
After Treatment Cost Elements	Demobilization - Demobilization of equipment, material, and personnel	9,827	lump sum	9,827

2.5 Performance

Treatment technology performance data are more difficult to standardize than the other items described in this Guide, such as site background information. Performance data vary by technology type, and are influenced by such factors as matrix characteristics, geologic setting (for in situ technologies), and design and operation of the technology. While performance is often characterized as a removal percentage or the concentration level attained, this information alone may not be adequate to assess the overall performance of the technology. Establishing performance levels for in situ processes is particularly challenging due to the difficulty involved in accurately characterizing the level and extent of contamination. Exhibit 7 lists the types of information which should be reported to the extent possible when reporting

performance-related information in order to provide analysts with a better understanding of the technology application.

Exhibit 7: Types of Treatment Technology Performance-Related Information

Performance-Related Topic	Type of Information
Types of Samples Collected	<ul style="list-style-type: none"> • Type of media sampled • Type of constituents analyzed • Use of surrogates (e.g., soil gas as a surrogate for soil borings)
Sample Frequency and Protocol	<ul style="list-style-type: none"> • Where samples were collected • How samples were collected • When samples were collected • Who collected samples
Quantity of Material Treated	<ul style="list-style-type: none"> • Quantity of material treated during application • For in situ technologies, area and depth of contaminated material treated
Untreated and Treated Contaminant Concentrations	<ul style="list-style-type: none"> • Measurement of initial conditions (even if not required to demonstrate compliance with cleanup criteria) • Measurement of contaminant concentration during and/or after treatment (noting if there are matched untreated/treated pairs of data, and/or whether there are operating data to correspond with performance data) • Assessment of percent removal achieved (noting procedure used to derive percent removal) • Correlations of performance data with other variables
Cleanup Objectives	<ul style="list-style-type: none"> • Cleanup goals or objectives • Criteria for ceasing operation
Comparison With Cleanup Objectives	<ul style="list-style-type: none"> • Assessment of whether technology operation achieved cleanup objectives • Assessment of whether the technology was operated to achieve reductions in contaminant concentrations beyond the established cleanup objectives
Analytical Methodology	<ul style="list-style-type: none"> • Analytical methodology used (including field screening or analyses, portable instrumentation, mobile laboratory, off-site laboratory, CLP procedures, nonstandard methods) • Exceptions to standard methodology

Exhibit 7 (Continued)

Performance-Related Topic	Type of Information
QA/QC*	<ul style="list-style-type: none"> Who had responsibility for QA/QC Type of QA/QC measures performed Level of procedures Exceptions to QA/QC protocol or data quality objectives
Other Residuals	<ul style="list-style-type: none"> Types of residuals generated (e.g., off-gasses, wastewaters, or sludges) Measurement of mass or volume, and contaminant concentration, in each treatment residual

*Note that only very general QA/QC information is recommended, with detailed reporting on an exceptions basis.

Example applications of the recommended procedures for two projects (one ex situ thermal desorption project, one in situ soil vapor extraction and bioventing project) are presented below in Exhibits 8 through 12. The exhibits illustrate the types of information which are typically described in more detail in a project report.

Exhibit 8. Example for Reporting Performance Information for an Ex Situ Project

(T H Agriculture & Nutrition Company Superfund Site, Albany, Georgia)	
Types of Samples Collected:	<ul style="list-style-type: none"> - Soil - Analyzed for organochlorine (OCL) pesticides
Sampling Frequency and Protocol:	<ul style="list-style-type: none"> - 18 composite samples collected over 3 month operating period
Quantity of Material Treated	<ul style="list-style-type: none"> - 4,318 tons of soil treated during thermal desorption application

Exhibit 8 (Continued)

Untreated and Treated Contaminant Concentrations:	<ul style="list-style-type: none"> - OCL pesticide concentrations (average) in untreated and treated soil shown in Exhibit 9 - Average untreated soil concentrations for specific pesticides ranged from 1.9 to 257.7 mg/kg - Average treated soil concentrations for specific pesticides ranged from <0.0383 to <3.6456 mg/kg; no matched untreated/treated data pairs available - Percent removal for specific pesticides ranged from 91.19 to 99.99% - Percent removal calculated by treatment vendor using one-half the reported detection limit for results identified as below detection limit (BDL)
Cleanup Objectives:	<ul style="list-style-type: none"> - 90% reduction for four OCL pesticides (BHC-alpha, BHC-beta, 4,4'-DDT, and toxaphene) - Total OCL pesticide concentration less than 100 mg/kg
Comparison With Cleanup Objectives:	<ul style="list-style-type: none"> - Achieved average percent reduction for four OCL pesticides greater than 98% - Achieved average treated soil total OCL pesticide concentration equal to 0.5065 mg/kg
Analytical Methodology:	<ul style="list-style-type: none"> - SW-846 Method 8080 for OCL pesticides - One exception to standard methodology identified (a wide-bore GC column was used instead of a packed GC column)
QA/QC:	<ul style="list-style-type: none"> - QA/QC review performed by contractors for EPA and PRP indicated no technical data quality concerns
Other Residuals:	<ul style="list-style-type: none"> - Off-gasses generated by thermal desorber - Off-gasses results and standards shown in Exhibit 10

Exhibit 9: Example for Reporting Untreated and Treated Contaminant Concentrations

Constituent/ Parameter	Cleanup Goal	Average Untreated Soil Concentratio n (from proof-of- process test) (mg/kg)	Average Treated Soil Concentratio n (from full- scale operation) (mg/kg)	Range of Percent Removal (%)	Average Percent Removal (%)
BHC-alpha	90% measured reduction in concentratio n	1.9	BDL (0.0399)	91.19 to 99.96	98.97
BHC-beta	90% measured reduction in concentratio n	4.5	BDL (0.0383)	96.22 to 99.98	99.57
4,4'-DDT	90% measured reduction in concentratio n	212.6	BDL (0.0710)	99.85 to 99.99	99.98
Toxaphene	90% measured reduction in concentratio n	257.7	BDL (3.6456)	93.40 to 99.97	99.29
Total OCL Pesticides	<100 mg/kg	Not available	0.5065	--	--

BDL - Below detection limit.

Exhibit 10: Example for Reporting Residuals Data

Constituent/Paramete r	Air Emission Standard	Average Emission Rate or Concentration	Range of Emission Rates or Concentrations
Stack Gas Total Hydrocarbons	100 ppmv	11.9 ppmv	2.9 to 35.5 ppmv
HCl Mass Emission Rate	<4 lbs/hr	0.12 lbs/hr	0.12 to 0.13 lbs/hr
Stack Gas Particulates	<0.08 gr/dscf	0.0006 gr/dscf	0.0005 to 0.0007 gr/dscf
Toxaphene	1.2 ppbv	7.6 x 10 ⁻⁵ ppbv	Not available

4,4'-DDT	1.0 ppbv	6.1×10^{-6} ppbv	Not available
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Exhibit 11: Example for Reporting Performance Information for an In Situ Project

(Hill Air Force Base Site 914, Ogden, Utah)	
Types of Samples Collected:	<ul style="list-style-type: none"> - Soil and soil gas (soil gas samples used to assess biodegradation) - Analyzed for Total Petroleum Hydrocarbons (TPH), Oxygen (O₂), and Carbon Dioxide (CO₂)
Sampling Frequency and Protocol:	<ul style="list-style-type: none"> - Soil samples collected in 15 vent wells at 5 feet depth intervals to 66 feet total depth - Continuous monitoring of soil gas O₂ and CO₂ concentrations
Quantity of Material Treated:	<ul style="list-style-type: none"> - 5,000 cubic yards contaminated by spill - Approximate extent of 10,000 mg/kg JP-4 contour covered area 100 by 150 feet
Untreated and Treated Contaminant Concentrations:	<ul style="list-style-type: none"> - TPH concentrations (average) and TPH removal over time are shown in Exhibit 12 - Soil TPH concentrations in untreated soil ranged from <20 to 10,200 mg/kg, with average soil TPH concentration of 411 mg/kg - 211,000 pounds of JP-4 removed from soil in two years of system operation - Removal rate ranged from 20 to 400 pounds per day
Cleanup Objectives:	<ul style="list-style-type: none"> - Soil TPH limit of 38.1 mg/kg set by Utah Department of Health
Comparison With Cleanup Objectives:	<ul style="list-style-type: none"> - Average soil TPH concentration after treatment less than 6 mg/kg
Analytical Methodology:	<ul style="list-style-type: none"> - Identification of methodology not available at this time - No exceptions to standard methodology identified
QA/QC:	<ul style="list-style-type: none"> - Type of QA/QC measures performed not available at this time - No exceptions to QA/QC protocol or data quality objectives identified
Other Residuals:	<ul style="list-style-type: none"> - Off-gasses generated by extraction process treated by catalytic oxidation

Exhibit 12: Example for Reporting Untreated and Treated Contaminant Concentrations and Contaminant Removals

Hill AFB Building 914 Soil Samples

Key:

Before - Mean Total Petroleum Hydrocarbon (TPH) Concentrations at 5-Foot Intervals Prior to Venting

Intermediate - Mean TPH Concentration After High Rate Operating Mode Venting but Before Low Flow Operating Mode with Moisture and Nutrient Addition

After - Mean TPH Concentration After Low Flow Operating Mode with Moisture and Nutrient Addition

Cumulative Hydrocarbon Removal at Hill AFB Building 914 Soil Venting Site

Cumulative Hydrocarbon Removal (Volatilized and Biodegraded) at Hill AFB, Utah, Soil Venting Site (from 18 December 1988 to 14 November 1990)

3.0 IMPLEMENTATION AND FUTURE CONSIDERATIONS

Each Roundtable agency is responsible for developing its own plan for implementing the procedures recommended in this Guide. Successful implementation requires only that Agencies agree to use the baseline or core data elements when they collect cost and performance data for full-scale remediation projects; the Agencies are free to collect any additional data necessary to meet their particular needs, and to report this information in a format of their choice.

To date, the basic report formats being adopted by Agencies include descriptions of site background and conditions, nature and extent of contamination, treatment system performance, cost, regulatory and institutional issues, and lessons learned. During Work Group meetings, the importance of the lessons learned analyses was often cited. This discussion describes experience in designing, constructing, or operating the treatment system that could improve future projects. Discussions of how problems were solved and suggestions or recommendations for future improvements are valuable to future technology users.

During Work Group meetings, members discussed whether the recommended procedures in the Guide also should apply to pilot-scale studies and demonstration projects. These studies are conducted to collect detailed information and are typically well documented. However, summarizing results from these efforts and from treatability studies as suggested in this Guide will allow more meaningful comparisons and assessments of technologies. Agencies may choose to apply parts or all of this guidance to pilot-scale and demonstration studies.

Ease of access to the cost and performance information prepared under this guidance is still an issue. The Work Group will continue to meet to discuss ways to improve the dissemination of information on remedial technologies including electronic distribution of full-scale cleanup reports.

This Guide is meant to be a starting point for improving the documentation of cleanup projects. The procedures presented here will be amended in the future to reflect agency experience in using the Guide and documenting completed projects. The Guide also will be expanded to add new technologies as they emerge into full-scale application.

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Table 1

**Site Background:
Waste Management Practice That Contributed to Contamination***

Management Practice	
Aboveground Storage Tank	Open Burn/Open Detonation Area
Co-Disposal Landfill	Petroleum, Oil, Lubricant (POL) Line
Contaminated Aquifer - Contamination Source Unknown	Recycling (other than as primary operation)
Discharge to Sewer/Surface Water	Road Oiling
Disposal Pit	Spill
Dumping—Unauthorized	Storage—Drums/Containers
Explosive/Ordnance Disposal Area	Surface Disposal Area
Fire/Crash Training Area	Surface Impoundment/Lagoon
Incineration Residuals Handling	Underground Injection
Industrial Landfill	Underground Storage Tank
Lake or River Disposal	Waste Pile
Landfarm/Land Treatment Facility	Waste Treatment Plant
Manufacturing Process	Other (explain)
Ocean Disposal	

*Derived from EPA's VISITT and DoD's Installation Restoration Program efforts.

Table 2
Media to be Treated*

Media	
Soil Sludge Solid (e.g., slag, rock) Sediment Light Non-aqueous Phase Liquids (LNAPL) Dense Non-aqueous Phase Liquids (DNAPL)	Groundwater Surface Water Leachate Buildings Products, Chemicals

*Treatment of these media include both in situ and ex situ applications. Derived from EPA's VISITT database and the interagency WBS.

Table 3
Contaminant Groups*

Contaminant Groups	
<ul style="list-style-type: none"> • Organic Compounds <ul style="list-style-type: none"> -- Volatiles—Halogenated -- Volatiles—Nonhalogenated <ul style="list-style-type: none"> - BTEX - TPH - Ketones - Styrene -- Semivolatiles—Halogenated <ul style="list-style-type: none"> - Dioxins/Furans - PCBs - Organic corrosives - Organic cyanides - Organic pesticides/herbicides -- Semivolatiles—Nonhalogenated <ul style="list-style-type: none"> - Phthalates - Polynuclear aromatic hydrocarbons (PAHs) - Organic pesticides/herbicides 	<ul style="list-style-type: none"> • Inorganic Compounds <ul style="list-style-type: none"> -- Asbestos -- Heavy metals (e.g., Be, Cd, Cr, Cu, Hg, Pb, Ni, Se, Zn) -- Inorganic cyanides -- Inorganic corrosives -- Nonmetallic elements (e.g., As) -- Radioactive elements (e.g., Ce, Rb, Sr, U) -- Radionuclides (e.g., tritium) • Radon • Explosives/Propellants • Organometallic Compounds <ul style="list-style-type: none"> Pesticides/herbicides

*Examples of contaminant groups targeted for application of remedial technology. Derived from EPA's VISITT database and Superfund LDR 6A/6B Guides, and the interagency WBS.

Table 4**Primary Treatment Systems***

Soil In Situ	Soil Ex Situ	Groundwater In Situ	Groundwater Ex Situ
Bioremediation Bioventing Soil Flushing Soil Vapor Extraction Solidification/ Stabilization Thermally Enhanced Recovery (i.e., EM, RF) Vitrification	Chemical Reduction/ Oxidation Dehalogenation Incineration Land Treatment Physical Separation Pyrolysis Slurry Phase Bioremediation Soil Washing Solid Phase Bioremediation Solidification/ Stabilization Solvent Extraction Thermal Desorption Vitrification	Bioremediation Chemical Reduction/ Oxidation Cosolvent Flushing Dual Phase Extraction Electrokinetics Hot Water/Steam Flushing/Stripping Natural Attenuation Passive Treatment Walls Sparging Surfactants	Pump and Treat with: Air Stripping Bioreactors Carbon Adsorption Chemical Treatment Membrane Filtration Solar Detoxification UV Oxidation

*Derived from EPA's VISITT database and a screening matrix prepared jointly by EPA and Air Force personnel.

Table 5**Supplemental Treatment Systems***

Pretreatment (Solids)	Augmentation (for In Situ Process)	Post-Treatment (Air)	Post-Treatment (Solids)	Post-Treatment (Water)
Crushing Dewatering Milling Mixing Nutrient Injection Screening Shredding	Horizontal Wells Hydraulic Fracturing Mixing Pneumatic Fracturing	Baghouse Biofiltration Carbon Adsorption Catalytic Oxidation Condenser Corona Cyclone Scrubber Thermal Destruction	Compaction Incineration Quench Stabilization	Air Stripping Biological Carbon Adsorption Centrifugation Chemical Decanting Filtration Ion Exchange Neutralization

*Derived from EPA's VISITT database and a screening matrix prepared jointly by EPA and Air Force personnel.

Table 6

**Suggested Parameters to Document Full-Scale Technology Applications:
Matrix Characteristics Affecting Treatment Cost or Performance**

Matrix Characteristics	In Situ Soil Remediation			Ex Situ Soil Remediation		
	Soil Bioventing	Soil Flushing	Soil Vapor Extraction	Land Treatment	Composting	Slurry Phase Soil Bioremediation
SOIL TYPES						
Soil Classification	●	●	●	●	●	●
Clay Content and/or Particle Size Distribution	●	●	●	●	●	●
AGGREGATE SOIL PROPERTIES						
Hydraulic Conductivity/Water Permeability		●				
Moisture Content	●		●			
Air Permeability	●		●			
pH	●	●		●	●	
Porosity	●		●			
Transmissivity						
ORGANICS						
Total Organic Carbon	●	●	●			
Oil & Grease or Total Petroleum Hydrocarbons		●				
Nonaqueous Phase Liquids	●	●	●			
MISCELLANEOUS^(B)				(B)		

^(A) Matrix characteristics shown for pump and treat are for groundwater pumping/extraction. Treatment process selection may affect the list of desirable characteristics to be documented.

^(B) Miscellaneous matrix characteristics include field capacity for land treatment; cation exchange capacity for soil washing of metal-containing wastes; Btu value, halogen content, and metal content for incineration; and bulk density and Lower Explosive Limit for thermal desorption.

Note: Some matrix characteristics listed above (e.g., moisture content and pH) are not identified on Table 6 as affecting treatment cost or performance since these are typically modified during the operation of the technology.

Table 6
(Continued)

Therefore, they are listed on Table 7 as operating parameters affecting treatment cost or performance.

Table 6
(Continued)

Ex Situ Soil Remediation				Groundwater Remediation			Matrix Characteristics
Soil Washing	Stabiliz a-tion	Inciner a-tion	Thermal Desorptio n	In Situ Groundwater Bioremediatio n	Groundwater Sparging	Pump and Treat ^(A)	
SOIL TYPES							
●	●	●	●	●	●	●	Soil Classification
●	●	●	●	●	●	●	Clay Content and/or Particle Size Distribution
AGGREGATE SOIL PROPERTIES							
				●	●	●	Hydraulic Conductivity/Water Permeability
	●	●	●				Moisture Content
							Air Permeability
	●			●			pH
					●		Porosity
				●		●	Transmissivity
ORGANICS							
●	●	●		●			Total Organic Carbon
	●		●			●	Oil & Grease or Total Petroleum Hydrocarbons
				●	●	●	Nonaqueous Phase Liquids
(B)		(B)	(B)				MISCELLANEOUS ^(B)

Non-Matrix Characteristics Affecting Cost or Performance:	
Contaminants: type and concentration of contaminants	Quantity of Material Treated: related to economies of scale
Environmental Setting for in situ technologies: geology, stratigraphy, and hydrogeology	Cleanup Goals/Requirements: cleanup levels, schedules, sampling, and analysis

Table 7

**Suggested Parameters to Document Full-Scale Technology Applications:
Operating Parameters Affecting Treatment Cost or Performance**

Operating Parameters	In Situ Soil Remediation			Ex Situ Soil Remediation		
	Soil Bioventing	Soil Flushing	Soil Vapor Extraction	Land Treatment	Composting	Slurry Phase Soil Bioremediation
SYSTEM PARAMETERS						
Air Flow Rate	●		●		●	●
Mixing Rate/Frequency				●	●	●
Moisture Content	●			●	●	●
Operating Pressure/Vacuum	●		●			
pH		●		●	●	●
Pumping Rate		●				
Residence Time				●	●	●
System Throughput						●
Temperature	●			●	●	●
Washing/Flushing Solution Components/Additives and Dosage		●				
BIOLOGICAL ACTIVITY						
Biomass Concentration						●
Microbial Activity						
Oxygen Uptake Rate	●				●	
Carbon Dioxide Evolution	●					
Hydrocarbon Degradation	●			●	●	●
Nutrients and Other Soil Amendments	●			●	●	●
Soil Loading Rate					●	

Table 7
(Continued)

Ex Situ Soil Remediation				Groundwater Remediation			Operating Parameters
Soil Washing	Stabiliz a-tion ^(A)	Inciner a-tion	Thermal Desorptio n	In Situ Groundwater Biodegradatio n	Groundwater Sparging	Pump and Treat	
SYSTEM PARAMETERS							
		●		●	●		Air Flow Rate
							Mixing Rate/Frequency
							Moisture Content
					●		Operating Pressure/Vacuum
●				●			pH
						●	Pumping Rate
		●	●				Residence Time
●		●	●				System Throughput
	●	●	●				Temperature
●							Washing/Flushing Solution Components/Additives and Dosage
BIOLOGICAL ACTIVITY							
				●			Biomass Concentration
							Microbial Activity
							Oxygen Uptake Rate
							Carbon Dioxide Evolution
							Hydrocarbon Degradation
				●			Nutrients and Other Soil Amendments
							Soil Loading Rate

^(A) Additional operating parameters for stabilization include additives and dosage, curing time, compressive strength, volume increase, bulk density, and permeability.

Table 8

Matrix Characteristics: Measurement Procedures and Potential Effects on Treatment Cost or Performance

Matrix Characteristics	Measurement Procedures	Important to Document Measurement Procedure?	Potential Effects on Cost or Performance
Soil Types			
Soil Classification	Soil classification is a semi-empirical measurement of sand, silt, clay, gravel, and loam content. Several soil classification schemes are in use and include the ASTM Standard D 2488-90, <u>Practice for Description and Identification of Soils (Visual-Manual Procedure)</u> , the USDA and CSSC systems.	Yes	Soil classification is an important characteristic for assessing the effect on cost or performance of all technologies shown on Table 6. For example, in soil vapor extraction, sandy soils are typically more amenable to treatment than clayey soils. (See related information under clay content and/or particle size distribution.)
Clay Content and/or Particle Size Distribution	Clay content and/or particle size distribution is measured using a variety of soil classification systems, including ASTM D 2488-90 under soil classification.	Yes	Clay and particle size distribution affect air and fluid flow through contaminated media. In slurry phase bioremediation systems, particle size affects ability to hold media in suspension. In soil washing, the particle size/contaminant concentration relationship affects the potential for physical separation and volume reduction. For thermal desorption systems, clay and particle size affects mass and heat transfer, including agglomeration and carryover to air pollution control devices.

Table 8 (Continued)

Matrix Characteristics: Measurement Procedures and Potential Effects on Treatment Cost or Performance

Matrix Characteristics	Measurement Procedures	Important to Document Measurement Procedure?	Potential Effects on Cost or Performance
Aggregate Soil Properties			
Hydraulic Conductivity/ Water Permeability	Hydraulic conductivity/water permeability can be determined through several procedures. Hydraulic conductivity, which is a measure of the ease of water flow through soil, is typically calculated as a function of permeability or transmissivity. ASTM D 5126-90, <u>Guide for Comparison of Field Methods for Determining Hydraulic Conductivity in the Vadose Zone</u> , is a guide for determining hydraulic conductivity. Water permeability is often calculated by pumping out groundwater, measuring groundwater draw-down rates and recharge times through surrounding monitoring wells, and factoring in the distance between the wells and the pump. Method 9100 in EPA SW-846 is used to measure permeability, as well as several ASTM standards: D 2434-68 (1974), <u>Test Method for Permeability of Granular Soils (Constant Head)</u> , D 4630-86, <u>Test Method for Determining Transmissivity and Storativity of Low Permeability Rocks by In Situ Measurements Using the Constant Head Injection Test</u> , and D 4631-86, <u>Test Method for Determining Transmissivity and Storativity of Low Permeability Rocks by In Situ Measurements Using the Pressure Pulse Technique</u> .	Yes	This characteristic is important in groundwater remediation technologies including in situ groundwater bioremediation, groundwater sparging, and pump and treat systems. Hydraulic conductivity and water permeability affect the zone of influence of the extraction wells and, therefore, affects the number of wells needed for the remediation effort and the cost of operating the extraction wells.

Table 8 (Continued)

Matrix Characteristics: Measurement Procedures and Potential Effects on Treatment Cost or Performance

Matrix Characteristics	Measurement Procedures	Important to Document Measurement Procedure?	Potential Effects on Cost or Performance
Moisture Content	Procedures for measuring soil moisture content are standardized. Soil moisture content is typically measured using a gravimetric ASTM standard, D 2216-90, <u>Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock</u> .	No	The moisture content of the matrix typically affects the performance, both directly and indirectly, of in situ technologies such as bioventing and soil vapor extraction, and ex situ technologies such as stabilization, incineration, and thermal desorption. For example, air flow rates during operation of soil vapor extraction technologies are affected by moisture content of the soil. Thermal input requirements and air handling systems for incineration and desorption technologies can also be affected by soil moisture content. (Effects of moisture content on operation of technologies is discussed in Table 9).
Air Permeability	Air permeability is a measure of the ease of air flow through soil and is a calculated value. For example, air permeability may be calculated by applying a vacuum to soil with a pump, measuring vacuum pressures in surrounding monitoring wells, and fitting the results to a correlation derived by Johnson et al., 1990.	Yes	This characteristic is important for in situ soil remediation technologies that involve venting or extraction. Air permeability affects the zone of influence of the extraction wells, and, therefore, affects the number of extraction wells needed for the remediation effort and the cost of operating the extraction wells.

Table 8 (Continued)

Matrix Characteristics: Measurement Procedures and Potential Effects on Treatment Cost or Performance

Matrix Characteristics	Measurement Procedures	Important to Document Measurement Procedure?	Potential Effects on Cost or Performance
pH	pH is a measure of the degree of acidity or alkalinity of a matrix. Procedures for measuring and reporting pH are standardized and include EPA SW-846 Method 9045 and ASTM methods for soil (ASTM D 4972-89, <u>Test Method for pH of Soils</u>) and groundwater (ASTM D 1293-84).	No	The pH of the matrix can impact the solubility of contaminants and biological activity. Therefore, this characteristic can affect technologies such as soil bioventing, soil flushing, land treatment, composting, stabilization, and in situ groundwater bioremediation. pH can also affect the operation of treatment technologies (see Table 9). pH in the corrosive range (e.g., <2 and >12) can damage equipment and typically requires use of personal protection equipment and other special handling procedures.
Porosity	Porosity is the volume of air- or water-filled voids in a mass of soil. Procedures for measuring and reporting porosity are standardized. Porosity is measured by ASTM D 4404-84, <u>Test Method for Determination of the Pore Volume and Pore Volume Distribution of Soil and Rock by Mercury Intrusion Porosimetry</u> .	No	This characteristic is important for in situ technologies, such as soil bioventing, soil vapor extraction, and groundwater sparging, that rely upon use of a driving force for transferring contaminants into an aqueous or air-filled space. Porosity affects the driving force, and thus, the performance that may be achieved by these technologies.

Table 8 (Continued)

Matrix Characteristics: Measurement Procedures and Potential Effects on Treatment Cost or Performance

Matrix Characteristics	Measurement Procedures	Important to Document Measurement Procedure?	Potential Effects on Cost or Performance
Transmissivity	Transmissivity, the flow from a saturated aquifer, is the product of hydraulic conductivity and aquifer thickness.	No ¹	This characteristic is important for groundwater pump and treat or fluid cycling systems. Transmissivity affects the zone of influence in this type of remediation which impacts the number of wells and the cost of operating the wells.

¹The measurement of hydraulic conductivity is important to document; since transmissivity is a product of hydraulic conductivity and aquifer thickness, it would not be necessary to document the measurement procedure for this characteristic.

Table 8 (Continued)

Matrix Characteristics: Measurement Procedures and Potential Effects on Treatment Cost or Performance

Matrix Characteristics	Measurement Procedures	Important to Document Measurement Procedure?	Potential Effects on Cost or Performance
Organics			
Total Organic Carbon (TOC)	TOC is a measure of the total organic carbon content of a matrix. Measurement of TOC is standardized (e.g., Method 9060 in EPA SW-846).	No	TOC affects the desorption of contaminants from soil and impacts in situ soil remediation, soil washing, stabilization, and in situ groundwater bioremediation. TOC content may differ between uncontaminated and contaminated soil.
Oil & Grease (O&G) or Total Petroleum Hydrocarbons (TPH)	Procedures for measuring O&G and TPH are standardized. O&G is measured using Method 9070 in EPA SW-846, and TPH is measured using Method 9073. A TPH analysis is similar to an O&G analysis with an additional extraction step. TPH does not include non-petroleum fractions, such as animal fats and humic and fulvic acids.	No	O&G and TPH affect the desorption of contaminants from soil. For thermal desorption, elevated levels of TPH may result in agglomeration of soil particles, resulting in shorter residence times.
Nonaqueous Phase Liquids (NAPLs)	There is no standard measurement method for determining the presence of NAPLs; rather, their presence is determined by examining groundwater and identifying a separate phase. The presence of NAPLs is reported as either being present or not present.	Yes	NAPLs may be a continuing source of contaminants for in situ technologies. NAPLs may lead to increased contaminant loads and thus to greater costs or longer operating periods for achieving cleanup goals. Under certain conditions, NAPLs may directly interfere with the operation of the treatment process.

Table 9

Operating Parameters: Measurement Procedures and Potential Effects on Treatment Cost or Performance

Operating Parameters	Measurement Procedures	Documentation Required Due to Method Variability?	Potential Effects on Cost or Performance
System Parameters			
Air Flow Rate	The air flow rate is a parameter set for a vapor extraction or treatment system. The measurement of air flow rate is standardized (i.e., measured with flow meters).	No	Air flow rate affects the rate of volatilization of contaminants in technologies that rely on transferring contaminants from a soil or aqueous matrix to air, such as soil bioventing, soil vapor extraction, and groundwater sparging. For technologies involving oxidation processes, this parameter affects the availability of oxygen and the rate at which oxidation occurs (e.g., for biotreatment or incineration processes).
Mixing Rate/Frequency	Mixing rate or frequency is the rate of tilling for land treatment, the rate of turning for composting, and the rotational frequency of a mixer for slurry phase bioremediation.	No	The mixing rate affects the rate of biological activity (through increased contact between oxygen and contaminants) and volatilization of contaminants.

Table 9 (Continued)

Operating Parameters: Measurement Procedures and Potential Effects on Treatment Cost or Performance

Operating Parameters	Measurement Procedures	Documentation Required Due to Method Variability?	Potential Effects on Cost or Performance
Moisture Content	Procedures for measuring soil moisture content are relatively standardized. Soil moisture content is typically measured using a gravimetric ASTM standard: D 2216-90, <u>Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock</u> . Moisture content as a treatment system operating parameter characterizes the amount of water and aqueous reagent added to the soil (for example, moisture content for slurry phase bioremediation refers to the solid to liquid ratio).	No	The moisture content affects the rate of biological activity in soil bioventing, land treatment, composting, and slurry phase bioremediation technologies. Contaminants must be in an aqueous phase for biodegradation to occur, and water is typically added to a soil to maintain a sufficient level of moisture to support biodegradation.
Operating Pressure/Vacuum	Operating pressure or vacuum is measured using a pressure or vacuum gauge, such as a manometer. The measurement of this parameter is standardized.	No	Operating pressure/vacuum affects the rate of volatilization of contaminants in technologies that rely on transferring contaminants from a soil or aqueous matrix to air, such as soil bioventing, soil vapor extraction, and groundwater sparging.
pH	Procedures for measuring and reporting pH are standardized (e.g., Method 9045 in EPA SW-846). The pH of soil and groundwater is adjusted during ex situ treatment as an operating parameter via the addition of acidic and alkaline reagents.	No	pH affects the operation of technologies that involve chemical or biological processes, such as soil flushing, soil washing, and bioremediation processes. For example, in soil washing, contaminants are extracted from a matrix at specified pH ranges based on the solubility of the contaminant at that pH.

Table 9 (Continued)

Operating Parameters: Measurement Procedures and Potential Effects on Treatment Cost or Performance

Operating Parameters	Measurement Procedures	Documentation Required Due to Method Variability?	Potential Effects on Cost or Performance
Pumping Rate	Pumping rate is the volume of groundwater extracted from the subsurface. The pumping rate is measured through a production well or treatment system using a flow meter or a bucket and stopwatch.	No	Pumping rate affects the amount of time required to remediate a contaminated area, and is important for technologies that involve extraction of groundwater, such as soil flushing, and pump and treat.
Residence Time	Residence time is the amount of time that a unit of material is processed in a treatment system. Residence time is measured by monitoring the length of time that a unit of soil is contained in the treatment system.	No	Residence time is important for ex situ technologies, such as land treatment, composting, slurry-phase soil bioremediation, incineration, and thermal desorption, to measure the amount of time during which treatment occurs.
System Throughput	System throughput is the amount of material that is processed in a treatment system per unit of time.	No	System throughput affects the costs for capital equipment required for a remediation and operating labor for ex situ technologies such as slurry phase soil bioremediation, soil washing, incineration, and thermal desorption.
Temperature	Temperature is measured using a thermometer or thermocouple.	No	For bioremediation technologies, temperature affects rate of biological activity. For stabilization, incineration, and thermal desorption, temperature affects the physical properties and rate of chemical reactions of soil and contaminants.

Table 9 (Continued)

Operating Parameters: Measurement Procedures and Potential Effects on Treatment Cost or Performance

Operating Parameters	Measurement Procedures	Documentation Required Due to Method Variability?	Potential Effects on Cost or Performance
Washing/Flushing Solution Components/Additives and Dosage	The components and dosages of washing and flushing solutions are site- and waste-specific "recipes" of polymers, flocculants, and coagulants. The type and concentrations of additives for a particular treatment application are determined based on site and waste characterization, treatability and performance tests, and operator experience. The actual amounts added are measured based on the volume and concentration of additive solutions metered into the treatment system.	No	For soil flushing and washing technologies, the types and dosages of additives affects the solubility and rate of extraction for contaminants; and thus affects the costs for constructing and operating flushing and washing equipment.

Table 9 (Continued)

Operating Parameters: Measurement Procedures and Potential Effects on Treatment Cost or Performance

Operating Parameters	Measurement Procedures	Documentation Required Due to Method Variability?	Potential Effects on Cost or Performance
Biological Activity			
Biomass Concentration	Biomass concentration is the number of microorganisms per unit volume in a treated or untreated aqueous matrix. Biomass concentrations are typically measured by direct plate counts. Portable water test kits are available for field tests. Methods 10200 through 10400 from <u>Standard Methods for the Examination of Water and Wastewater</u> are used in laboratory analyses of biomass concentration.	Yes	Biomass concentration is an important parameter for slurry phase soil bioremediation and in situ groundwater biodegradation. Biomass is necessary to effect treatment and thus the concentration of biomass is directly related to performance.
Microbial Activity Oxygen Uptake Rate (OUR) Carbon Dioxide Evolution Hydrocarbon Degradation	Oxygen uptake, carbon dioxide evolution, and hydrocarbon degradation are all used to measure the rate of biodegradation in a treatment system. Oxygen uptake is measured using ASTM D 4478-85, <u>Standard Test Methods for Oxygen Uptake</u> . Carbon dioxide evolution is measured with a carbon dioxide monitor. Hydrocarbon degradation is measured by sampling the influent to and effluent from the treatment system and analyzing samples for organic constituents, such as total petroleum hydrocarbons (EPA SW-846 Method 9073).	Yes	Microbial activity is an important parameter for soil bioventing, land treatment, composting, and slurry phase soil bioremediation technologies. Hydrocarbon degradation is commonly used as an indicator of treatment performance for these technologies, while OUR and carbon dioxide evolution are used in specific applications to supplement the hydrocarbon degradation data.

Table 9 (Continued)

Operating Parameters: Measurement Procedures and Potential Effects on Treatment Cost or Performance

Operating Parameters	Measurement Procedures	Documentation Required Due to Method Variability?	Potential Effects on Cost or Performance
Nutrients and Other Soil Amendments	Nutrients usually consist of nitrogen and phosphorus (and trace inorganic constituents such as calcium and magnesium), and are typically reported as a ratio of carbon to nitrogen to phosphorus. Carbon is measured as total organic carbon, with EPA SW-846 Method 9060. Nitrogen is measured as both ammonia nitrogen using ASTM D 1426-89, <u>Test Methods for Ammonia Nitrogen in Water</u> , and as nitrite-nitrate using ASTM D 3867-90, <u>Test Method for Nitrite-Nitrate in Water</u> . Phosphorus is measured using ASTM D 515-88, <u>Test Methods for Phosphorus in Water</u> . Calcium and magnesium are measured using ASTM D 511-88, <u>Test Method for Calcium and Magnesium in Water</u> . Other soil amendments may include bulking agents for composting (e.g., sawdust).	Yes	Nutrients and other soil amendments can affect soil bioventing and in situ groundwater biodegradation as this parameter directly affects the rate of biological activity and, therefore, contaminant biodegradation. This is also applicable to ex situ soil remediation technologies such as land treatment, composting, and slurry phase soil bioremediation.
Soil Loading Rate	Soil loading rate is the amount of soil applied to a unit area of a composting system.	No	The soil loading rate affects the rate of biological activity and can impact the costs for operation.

Table 10

Interagency Work Breakdown Structure Cost Elements - Second Level

Interagency WBS #	Cost Element	Description*
Before Treatment Cost Elements		
33 01	Mobilization and Preparatory Work	Includes all preparatory work required prior to commencement of remedial action or construction, such as preconstruction submittals; construction plans; mobilization of personnel, facilities, and equipment; construction of temporary facilities; temporary utilities; temporary relocations; and setup of decontamination facilities and construction plant.
33 02	Monitoring, Sampling, Testing, and Analysis	Provides for all costs associated with air, water, sludge, solids and soil sampling, monitoring, testing, and analysis. Includes sample taking, shipping samples, and sample analysis by on-site and off-site laboratory facilities.
33 03	Site Work	Consists of site preparation, site improvements, and site utilities. Site preparation includes demolition, clearing, and earthwork. Site improvements include roads, parking, curbs, gutters, walks, and other hardscaping. Site utilities include water, sewer, gas, and other utility distribution. All work involving contaminated or hazardous material is excluded from this system. Storm drainage involving contaminated surface water is included under "Surface Water Collection and Control" (33 05). Note that topsoil, seeding, landscaping, and reestablishment of existing structures altered during remediation activities are included in "Site Restoration" (33 20).

Table 10 (Continued)

Interagency Work Breakdown Structure Cost Elements - Second Level

Interagency WBS #	Cost Element	Description*
33 05	Surface Water Collection and Control	Provides for the collection and control of contaminated surface water through storm drainage piping and structures, erosion control measures, and civil engineering structures such as berms, dikes, and levees. Includes transport to treatment plant.
33 06	Groundwater Collection and Control	Provides for the collection and control of contaminated groundwater through piping, wells, trenches, slurry walls, sheet piling, and other physical barriers. Includes transport to treatment plant.
33 07	Air Pollution/Gas Collection and Control	Includes the collection and control of gas, vapor, and dust.
33 08	Solids Collection and Containment	Provides for exhuming and handling of solid hazardous, toxic and radioactive waste (HTRW) through excavation, sorting, stockpiling, and filling containers. Provides for containment of solid waste through the construction of multilayered caps as well as dynamic compaction of burial grounds, cribs, or other waste disposal units. Includes transport to treatment plant.
33 09	Liquids/Sediments/Sludges Collection and Containment	Includes collection of HTRW-contaminated liquids and sludges through dredging and vacuuming, and the furnishing and filling of portable containers. Includes the containment of liquids and sludges through the construction of lagoons, basins, tanks, and dikes. Includes transport to treatment plant.
33 10	Drums/Tanks/Structures/Miscellaneous Demolition and Removal	Includes the demolition and removal of HTRW-contaminated drums, tanks, and other structures by excavation and downsizing. Also includes ordnance removal. Does not include filling portable hazardous waste containers or transport of wastes to treatment or disposal facilities. See "Solids Collection and Containment" (33 08), "Disposal (Other than Commercial)" (33 18), and "Disposal (Commercial)" (33 19).

Table 10 (Continued)

Interagency Work Breakdown Structure Cost Elements - Second Level

Interagency WBS #	Cost Element	Description*
Treatment		
33 11	Biological	Defined as the microbial transformation of organic compounds. May also alter inorganic compounds such as ammonia and nitrate, and change the oxidation state of certain metal compounds. Includes in-situ biological treatment such as land farming as well as activated sludge, composting, trickling filters, anaerobic, and aerobic digestion. Includes process equipment and chemicals required for treatment.
33 12	Chemical	Defined as the process in which hazardous wastes are chemically changed to remove toxic contaminants from the environment. Type of treatment included in this account are oxidation/reduction, solvent extraction, chlorination, ozonation, ion exchange, neutralization, hydrolysis, photolysis, dechlorination, and electrolysis reactions. Includes process equipment and chemicals required for treatment.
33 13	Physical	Defined as the physical separation of contaminants from solid, liquid, or gaseous waste streams; and are applicable to a broad range of contaminant concentrations. Physical treatments generally do not result in total destruction or separation of the contaminants in the waste stream, consequently post-treatment is often required. Type of physical treatment included in this account are filtration, sedimentation, flocculation, precipitation, equalization, evaporation, stripping, soil washing, carbon adsorption, gravimetric separation, and magnetic/paramagnetic separation. Includes process equipment and chemicals required for treatment.

Table 10 (Continued)

Interagency Work Breakdown Structure Cost Elements - Second Level

Interagency WBS #	Cost Element	Description*
33 14	Thermal	Defined as the destruction of wastes through exposure to high temperature in combustion chambers and energy recovery devices. Several processes capable of incinerating a wide range of liquid and solid wastes include fluidized bed, rotary kiln, multiple hearth, infrared, circulating bed, liquid injection, pyrolysis, plasma torch, wet air oxidation, supercritical water oxidation, molten salt destruction, detonation, and solar detoxification. Includes process equipment and chemicals required for treatment.
33 15	Stabilization/Fixation/Encapsulation	Improves the handling and physical characteristics of wastes, decreases the surface area, limits the solubility of pollutants, and detoxifies pollutants contained in wastes.
After Treatment Cost Elements		
33 17	Decontamination and Decommissioning (D&D)	Associated with shutdown and final cleanup of a nuclear or other facility. Includes facility shutdown and dismantling activities, preparation of decommissioning plans, procurement of equipment and materials, research and development, spent fuel handling, and hot cell cleanup.
33 18	Disposal (Other than Commercial)	Provides for the final placement of HTRW or ordnance at facilities owned or controlled by the Government, including the operation of the facility. An example would be the disposal of wastes through burial at a DOE nuclear facility or ordnance disposal at DoD facilities. The costs associated with this include storage, handling, disposal fees and transportation to the final Destruction/Disposal/Storage facility. Excluded is the transportation to a facility for treatment prior to disposal. Disposal may be accomplished through the use of secure landfills, surface impoundments, deep well injection, or incineration.

Table 10 (Continued)

Interagency Work Breakdown Structure Cost Elements - Second Level

Interagency WBS #	Cost Element	Description*
33 19	Disposal (Commercial)	Provides for the final placement of HTRW at third party commercial facilities that charge a fee to accept waste depending on a variety of waste acceptance criteria. Fees are assessed based on different waste categories, methods of handling, and characterization. Disposal may be accomplished through the use of secure landfills, surface impoundments, deep well injection, or incineration. Includes transportation to the final Destruction/Disposal/Storage facility. Excludes transportation to a facility for treatment prior to disposal.
33 20	Site Restoration	Includes topsoil, seeding, landscaping, restoration of roads and parking, and other hardscaping disturbed during site remediation. Note that all vegetation and planting is to be included as well as the installation of any site improvement damaged or altered during construction. All vegetation and plating for the purpose of erosion control during construction activities should be placed under "Erosion Control" (33 05 13). Treated soil used as backfill will be placed under "Disposal (Other than Commercial)" (33 18). All new site improvements, those not disturbed during construction, are to be included under "Site Work" (33 03).
33 21	Demobilization	Provides for all costs associated with plant takedown and removal of temporary facilities, utilities, equipment, material, and personnel.
33 9X	Other (use numbers 90-99)	Includes all Hazardous, Toxic, Radioactive Waste Remedial Action work not described by the above listed categories.

*Excerpted from the interagency Hazardous, Toxic, and Radioactive Waste (HTRW) Remedial Action (RA) Work Breakdown Structure, April 1993.

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Work Breakdown Structure and Historical Cost Analysis System developed by an Interagency Cost Estimating Group representing EPA, DOE, USACE, NAVFAC, and USAF - see attached discussion for whom to contact for additional information on the Work Breakdown Structure and Historical Cost Analysis System.

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Appendix A

Site Background: Historical Activity That Generated Contamination -
Examples of SIC Codes Most Likely to Apply to Contaminated Sites

Work Breakdown Structure and Historical Cost
Analysis System

Ad Hoc Work Group Members - Cost and Performance
Information

Federal Remediation Technologies Roundtable
Member Roster

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Site Background:
Historical Activity That Generated Contamination -
Examples of SIC Codes Most Likely to
Apply to Contaminated Sites

Activity	SIC Code*
Agricultural Services	
Soil Preparation Services	0711
Crop Preparation Services for Market, Except Cotton	0723
Ginning	0723A
-- Fumigation	
Metal Mining	
Iron Ores	1011
Copper Ores	1021
Lead and Zinc Ores	1031
Gold Ores	1041
Silver Ores	1044
Ferroalloy Ores, except Vanadium	1061
Metal Mining Services	1081
Uranium-Radium-Vanadium Ores	1094
Miscellaneous Metal Ores, NEC	1099
Oil and Gas Extraction	
Crude Petroleum and Natural Gas	1311
Natural Gas Liquids	1321
Drilling Oil and Gas Wells	1381
Oil and Gas Exploration Services	1382
Oil and Gas Field Services, NEC	1389
Mining and Quarrying of Non-Metallic Minerals, Except Fuels	
Crushed and Broken Stone, NEC	1429
Chemical and Fertilizer Mineral Mining, NEC	1479
Miscellaneous Non-Metallic Mining, Except Fuels	1499
Lumber and Wood Products, Except Furniture	
Wood Preserving	2491
-- Copper Chromated Arsenic (CCA)	2491A
-- Creosote	2491B
-- Pentachlorophenol	2491C
Chemicals and Allied Products	
Industrial Inorganic Chemicals, NEC	2819
Synthetic Rubber (Vulcanizable Elastomers)	2822
Industrial Organic Chemicals, NEC	2869
-- Town Gas	2869A
Pesticides and Agricultural Chemicals, NEC	2879
Explosives	2892

NEC = Not elsewhere classified.

Site Background:
Historical Activity That Generated Contamination -
Examples of SIC Codes Most Likely to
Apply to Contaminated Sites
(Continued)

Activity	SIC Code*
Petroleum Refining and Related Industries Petroleum Refining	2911
Rubber and Miscellaneous Plastics Products Custom Compounding of Purchased Plastic Resins	3087
Primary Metal Industries Steel Works, Blast Furnaces (Including Coke Ovens), and Rolling Mills -- Coke Ovens Gray and Ductile Iron Foundries Primary Smelting and Refining of Copper Primary Production of Aluminum Primary Smelting and Refining of Nonferrous Metals, Except Copper and Aluminum Secondary Smelting and Refining of Nonferrous Metals	3312 3312A 3321 3331 3334 3339 3341
Fabricated Metal Products, Except Machinery and Transportation Equipment Electroplating, Polishing, Anodizing, and Coloring Coating, Engraving, and Allied Services Small Arms Ammunition Ammunition, Except for Small Arms Small Arms Ordnance and Accessories, NEC	3471 3479 3482 3483 3484 3489
Electronic and Other Electrical Equipment and Components, Except Computer Equipment Power, Distribution and Specialty Transformers Switchgear and Switchboard Apparatus Printed Circuit Boards Semiconductors and Related Devices	3612 3613 3672 3674
Transportation Equipment Motor Vehicles and Passenger Car Bodies Aircraft Aircraft Parts and Auxiliary Equipment, NEC Ship Building and Repairing Railroad Equipment	3711 3721 3728 3731 3743

NEC = Not elsewhere classified.

Site Background:
Historical Activity That Generated Contamination -
Examples of SIC Codes Most Likely to
Apply to Contaminated Sites
(Continued)

Activity	SIC Code*
Motor Freight Transportation and Warehousing Farm Product Warehousing and Storage -- Grain Storage	4221 4221A
Transportation by Air Airports, Flying Fields, and Airport Terminal Services	4581
Pipelines, Except Natural Gas Crude Petroleum Pipelines Refined Petroleum Pipelines	4612 4613
Electric, Gas, and Sanitary Services Electric Services Natural Gas Transmission Water Supply -- Groundwater Supply Refuse Systems --Co-disposal landfill --Industrial landfill --Open dump --Sand and gravel pit disposal --Salvage yard/junk yard --Cement kiln operations --Incinerator --Radioactive waste disposal --Waste processing facility, miscellaneous	4911 4922 4941 4941A 4953 4953A 4953B 4953D 4953E 4953F 4953L 4953M 4953R 4953W
Wholesale Trade - Durable Goods Scrap and Waste Materials -- Recycling Batteries -- Recycling (Other - describe)	5093 5093A 5093B
Personal Services Dry Cleaning Plants, Except Rug Cleaning	7216
Business Services Business Services, NEC -- Solvents Recovery	7389 7389A
Health Services General Medical and Surgical Hospitals Medical Laboratories -- Miscellaneous Laboratories	8062 8071 8071A

NEC = Not elsewhere classified.

Site Background:
Historical Activity That Generated Contamination -
Examples of SIC Codes Most Likely to
Apply to Contaminated Sites
(Continued)

Activity	SIC Code*
Public Administration	
National Security	9711
--Miscellaneous	9711A
--Ordnance Production and Storage	9711B
--Ordnance Testing and Maintenance	9711C
Land, Mineral, Wildlife, and Forest Conservation	9512
--Dept. of Agriculture	9512A
--Dept. of Interior	9512B
Regulation and Administration of Communications, Electric, Gas, and Other Utilities	9631
--Dept. of Energy	9631A

*Nonstandard descriptors (e.g., A, B, C) are shown to provide additional information about SIC code.

Source: *Standard Industrial Classification Manual*, 1987.

NEC = Not elsewhere classified.

Work Breakdown Structure and Historical Cost Analysis System

The Work Breakdown Structure (WBS) and Historical Cost Analysis System (HCAS) resulted from the collective efforts of cost and project management professionals. As early as 1989, the Interagency Cost Estimating Group (ICEG) for Hazardous, Toxic, and Radioactive Waste (HTRW), a group under the sponsorship of EPA, began meeting to discuss methods of increasing the effectiveness of cost management (e.g., scoping, estimating, and controlling) for environmental restoration projects. The participants include environmental and cost professionals from EPA, DOE, U.S. Army Corps of Engineers, Naval Facilities Engineering Command, and Air Force and their counterparts in the private sector including federal contractors and other interested parties. A subcommittee of the ICEG, with participants from Navy, Army, Air Force, EPA, and DOE, formulated the WBS and HCAS. The WBS and HCAS are the result of insights, needs, and ideas from a broad spectrum of experience within the environmental restoration arena.

The HCAS has been developed to collect and view HTRW project information in the standard WBS format. HCAS is a PC-based software program which facilitates the collection and retrieval of historic project information and costs. The HCAS is available on the first quarter 1995 Construction Criterion Base (a CD-ROM published by the National Institute of Building Sciences) and will be the vehicle used to record and disseminate project information.

To continue towards the goal of widespread participation in the collection and sharing of cost information among environmental restoration professionals, Logistics Management Institute (LMI) is supporting the work of the ICEG. LMI, a not-for-profit corporation, operates a federally-funded research and development center that is dedicated to providing objective counsel to a wide array of government Agencies.

LMI is serving as the central collection and dissemination point for the project information submitted from various participating groups. LMI will provide support regarding the implementation of the WBS and HCAS, quality control of incoming data and the solicitation of additional participants.

WBS and HCAS information may be obtained from:

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